CHAPTER 5

E.M.F. SOURCES

It has been stressed that current will not flow unless there is an e.m.f. to provide a source of electrons. There are many different methods of producing an electromotive force and continuous research is revealing sources that were unknown until recent times. This chapter will mention those sources which are in general use at this point in time, while later chapters will discuss these sources in greater detail.

5.1 WET PRIMARY CELL

An electrolyte is a substance which will disassociate into positive and negative ions. If any two different metals are placed in an electroylyte an e.m.f. will be produced between the two materials. The combination of the two different materials (called electrodes) and the electrolyte, is known as a cell. Different combinations of electrode materials produce different values of e.m.f. One of the earliest primary cells consisted of copper and zinc electrodes immersed in dilute sulphuric acid. (Figure 5.1).

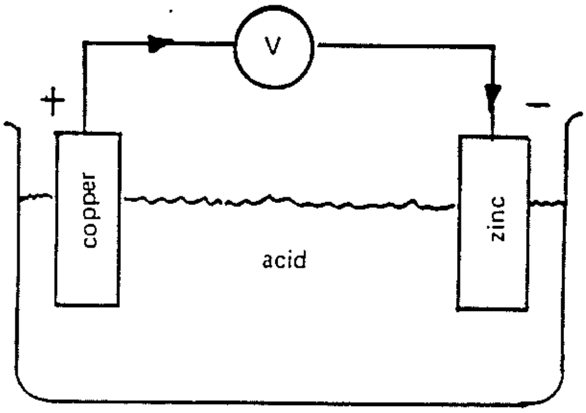

Figure 5.1

This combination produces an e.m.f. of approximately 1.1 volts. Current (not electrons) flows from the copper electrode to the zinc electrode, outside the cell, if a circuit is connected to the cell. Chemical reactions occur at the electrodes when the cell delivers current. In the primary cell, chemical reactions at the negative electrode causes the electrode to dissolve into the electrolyte. This chemical reaction cannot be reversed. Very little use is made of the primary cell in its original state due to its lack of mobility.

5.2 DRY CELLS

A modern adaption of the wet primary cell is the dry cell. The origional dry cell has a positive rod of carbon and a negative electrode of zinc. The negative electrode is shaped in the form of a can to hold the electrolyte and the material that produces the e.m.f. The carbon rod is inserted into the centre of the can contents to allow the cell to deliver current to an external circuit. (Figure 5.2).

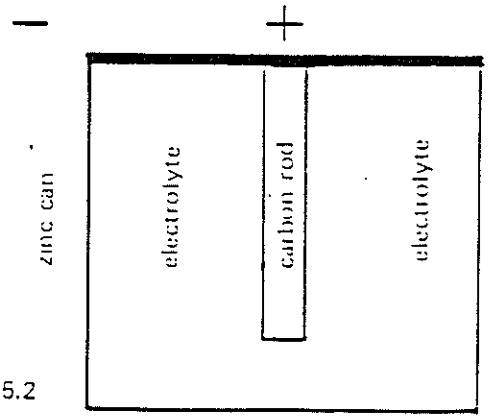

Figure 5.2

The cell produces an e.m.f. of approximately 1.5 volts when in an unused new condition. When the cell is delivering current, chemical reactions on the inside surface of the zinc container cause the container to gradually dissolve. This reaction cannot be reversed, so the cell can discharge electrons between electrodes only once. For this reason, the cell is said to be non-rechargeable and is classed as a primary cell.

The carbon zinc dry cell is being challenged as a small power source by the alkaline manganese cell. While looking very similar on the outside the internal construction of the cells is totally different. Because the alkaline manganese cell has the same active materials as the carbon zinc cell it produces the same e.m.f. namely 1.5 volts. The negative electrode (zinc) is contained inside a steel can along with the other active materials. Thus the container plays no part in the chemical reactions resulting in a longer life for the cell. The longer life and higher power output of an alkaline maganese cell are achieved at an increase in production costs. Both types of cells are used extensively in such small portable items as torches and radios.

Other dry cells, such as the button cells have been devised for specific functions. Mercury oxide cells produce an e.m.f. of 1.35 volts while the silver oxide cells produce an e.m.f. of 1.6 volts. These cells are used extensively in hearing aids and watches. A lithium cell that produces a t.p.d. of 1.9 volts has been evolved but its cost limits its marketing potential.

Small power dry cells that are used in portable electrical appliance are available in three sizes. These are the 'D' cell, the 'C' cell and the 'AA' cell. (Figure 5.3).

Figure 5.3

The selection depends on the space and the power requirements of the appliance.

5.3 SECONDARY CELLS

A secondary cell is one in which the chemical reactions at the electrodes can be reversed, that is, the cell can be continually discharged and recharged during use. There are many types of secondary cells, new combinations of electrodes and electrolytes being discovered from time to time. The two types in general use are -

The lead acid cell.

The alkaline cell.

(a) The Lead Acid Cell

The lead acid cell has plates as its electrodes. (Figure 5.4).

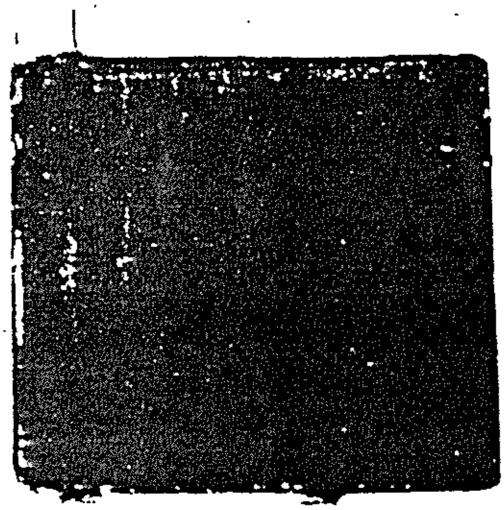

Figure 5.4

The plates are coated with a paste of lead compound which has its chemical composition changed during the charging and discharging cycles. When the cell is charged the lead compounds on the positive and negative plates are completely different. This difference, in the presence of an electrolyte (dilute sulphuric acid) produces an e.m.f. of 2 volts. As the cell is discharged the lead compounds on the plates tend to become identical, under which condition the cell e.m.f. and its power output is decreased.

The most common use of lead acid cells is in automobiles. Cells are connected together to produce an e.m.f. of 12 volts. This combining of cells is called a battery. The battery is then used to provide power to start the automobile and to supply current to the lights at night. The battery is recharged by a generator driven by the automobile's engine. Other uses of lead acid batteries are for electric traction and emergency lighting.

(b) Alkaline Cells

The two basic types of alkaline cells are the nickel iron and the nickel cadmium. While the nickel iron cell was used extensively twenty years ago, the reduced cost and better performance of the nickel cadium cell has caused them to virtually supercede the nickel iron cell. For this reason only the nickel cadmium cell will be used as an example of the alkaline cell. The alkaline cell has different active electrode materials than the lead acid cell, therefore it produces a different terminal voltage. The combination of nickel and cadmium produces an e.m.f. of between 1.3 and 1.4 volts. The plates are stainless steel and consists of pockets of nickel and cadmium oxides. (Figure 5.5).

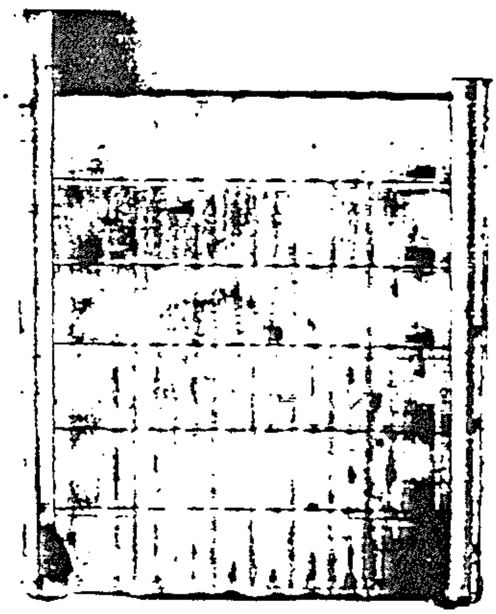

Figure 5.5

The chemical states of the oxides are changed during the charging and discharging cycles. The electrolyte in a non acidic solution. Alkaline cells are more reliable and last longer than lead acid cells but are far more expensive. Alkaline cells are also produced in the 'AA' size for use in very small portable devices such as calculators.

5.4 GENERATORS

Most students, at some time during their schooling have learnt about the magnet. They know that around the magnet is a force which will attract certain materials to that magnet. The force is called a magnetic field. If a conductor is moved so that it cuts across this magnetic field, an e.m.f. will be induced into the conductor. This principle is utilised in the electrical generator. Figure 5.6 shows an electrical machine which will produce both direct current and alternating current.

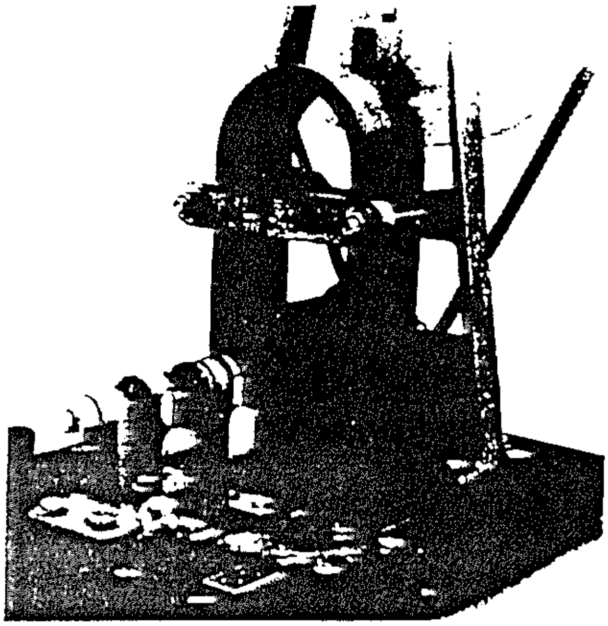

Figure 5.6

The horseshoe shape section provides a magnetic field as shown in figure 5.7.

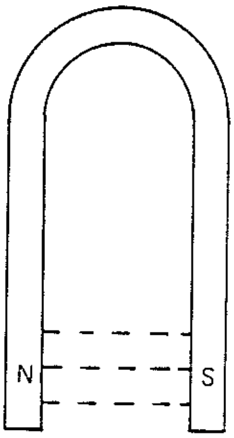

Figure 5.7

Magnetic poles are formed on the ends of the steel horseshoe. Between the poles are a number of conductors wound on an iron core. These conductors are connected to copper rings further down the shaft. The two rings closest to the conductors are known as sliprings and allow for the production of alternating current. The copper ring closest to the left hand side is actually two half rings. These half rings convert alternating current to direct current. This device is referred to as a commutator. When the drive handle attached to the shaft is turned the conductors cut through the magnetic field. An e.m.f. is induced into the conductors and transferred to the sliprings and the commutator.

In commercial generation of electricity the magnetic poles are formed by winding coils of wire around two steel cores and passing current through the coils. (Figure 5.8).

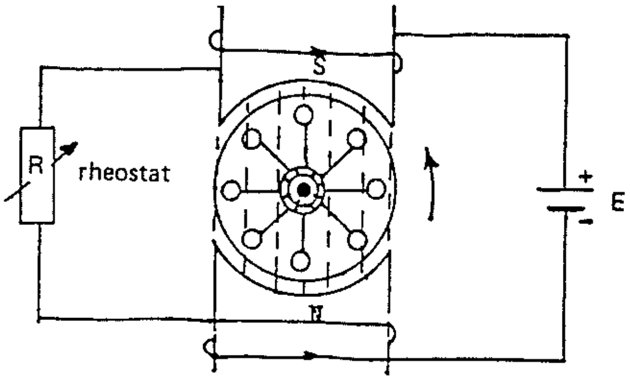

Figure 5.8

The current in the coils is in such a direction as to form opposite poles. A variable resistor, called a rheostat, varies the current in the coils, changing the strength of the magnetic field. This variation in magnetic field, changes the e.m.f. induced into the conductors and available at the sliprings or commutator. Because of the ease in adjusting the output voltage of a generator it has many uses, particularly in battery charging, lighting and emergency power supplies.

5.5 SOURCES PRODUCING VERY SMALL e.m.f.

These sources produce e.m.f.'s in the microvolt or millivolt range. The small values of e.m.f. usually have to be amplified before they can be put to practical use. Some of these small values of e.m.f. are produced by -

(i) the piezoelectric effect

(ii) heat

(iii) light

(iv) sun

(i) Piezoelectric Effect

Certain salt crystals will produce a minute value of e.m.f. if subject to a range of pressures. The limitation to this method is that the crystal can only be compressed to a fixed amount without the risk of damage. (Figure 5.9).

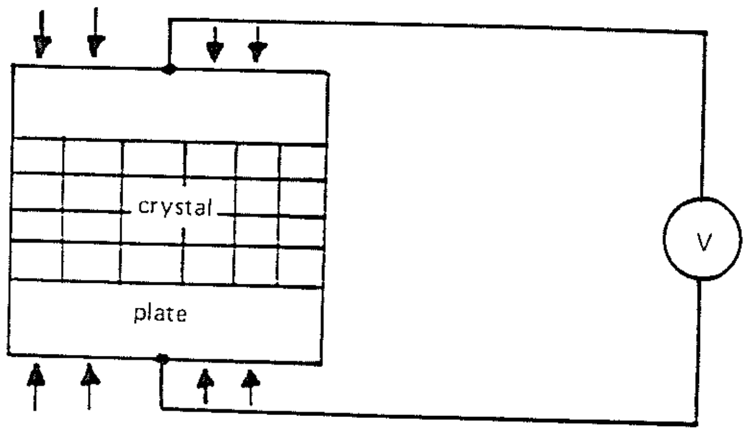

Figure 5.9

The small e.m.f.'s produced from these sources may be used to operate electronic devices such as microphones and gramophone styluses.

(ii) Heat

When two different metal conductors are joined together to form a loop, a thermocouple is created. If one of the junctions in the loop is heated, while the temperature of the other junction is kept constant, current will flow in the loop. An e.m.f. is produced while there is a difference in temperature between the two junctions. The value of the e.m.f. produced depends on the types of materials used and the difference in temperatures in the junctions of the loop. (Figure 5.10).

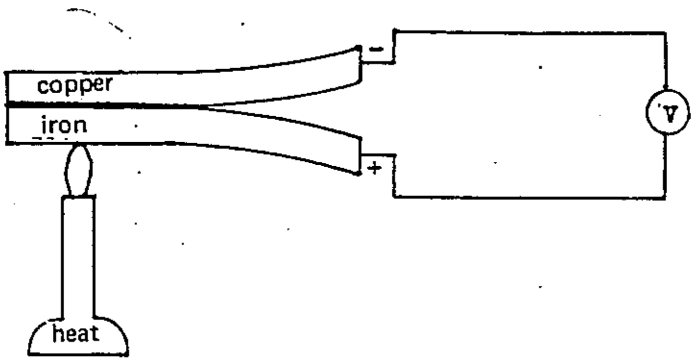

Figure 5.10

Thermocouples are used to measure the temperature in ovens and furnaces. A microammeter, calibrated to read degrees, is inserted in the cold end of the loop. The combination of the thermocouple and ammeter is called a pyrometer. Thermocouples are also used in control circuits of heating devices. The e.m.f. produced is used to activate equipment which may switch the heating device off or on.

(iii) Light

Light has been said to be a form of energy. Certain materials are light sensitive. This means that electrons within the material easily acquire increased energy when exposed to light. When a light sensitive material is placed on a backplate of non light sensitive material a photovoltaic cell is formed. If light is focussed onto the light sensitive material an e.m.f. is produced between the two materials. (Figure 5.11).

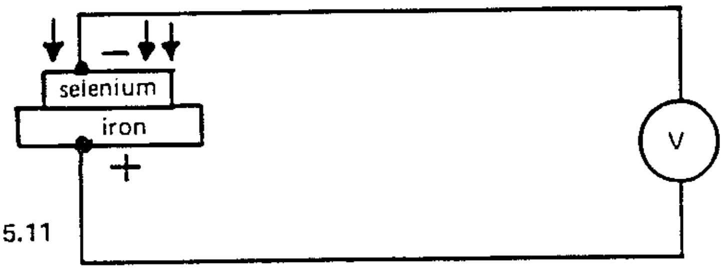

Figure 5.11

This type of source is used in such devices as light measuring meters associated with photography.

(iv) The Sun

If the two materials used in the photovoltaic cell are replaced with a suitable pn junction, a solar cell is formed. In the solar cell the p type material is very thin compared with the n type material. Light energy penetrating the p type material produces an e.m.f. between the exterior surfaces of the p and n type material. (Figure 5.12).

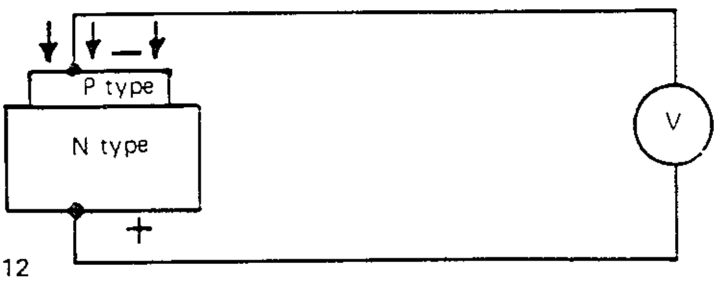

Figure 5.12

Solar cells provide power for radio receivers and transmitters used in satellites orbiting the earth.

TUTORIAL 1.5

Fractions

Fractions consist of two parts:

(a) The numerator, which is the quantity above the line.

(b) The denominator, which is the quantity below the line.

For example, in the fraction $\frac{2}{3}$, 2 is the numerator and 3 is the denominator. The most common term used in solving fraction problem is the **'lowest common denominator'** abbreviated to L.C.M., which is the figure that can be divided by all the denominators of the fractions in the problem. Examples of how to solve tutorials involves fractions are contained in the following paragraphs.

Example 5.2

evaluate $\frac{1}{2} + \frac{1}{3}$

(a) The L.C.M. of the fractions is $2 \times 3 = 6$

(b) This is written beneath the division line, $\frac{\quad}{6}$.

(c) Divide the first denominator into the L.C.M. and multiply the first numerator by the answer $\frac{6}{2} \times 1 = 3$

(d) Write this figure above the division line $\frac{3}{6}$

(e) Add the algebraic sign $\frac{3 +}{6}$

(f) Divide the L.C.M. by the next denominator and multiply its numerator by the answer $\frac{6}{3} \times 1 = 2$

(g) Write the figure above the division line $\frac{3 + 2}{6}$

(h) Evaluate the numerators $3 + 2 = 5$

(i) Complete the answer $\frac{5}{6}$

Example 5.2

evaluate $\frac{5}{6} - \frac{1}{4}$

Step (a) The smallest figure that will divide evenly by both denominators is 12

(b) $\frac{\quad}{12}$

(c) $\frac{12}{6} \times 5 = 10$

(d) $\frac{10}{12}$

(e) $\frac{10 -}{12}$

(f) $\frac{12}{4} \times 1 = 3$

(g) $\frac{10 - 3}{12}$

(h) 7

(i) $\frac{7}{12}$

Example 5.3

evaluate $\frac{5}{6} + \frac{2}{3} - \frac{4}{9}$

Step (a) L.C.M. is 18

(b) $\frac{\quad}{18}$

(c) $\frac{18}{6} \times 5 = 15$

(d) $\frac{15}{18}$

(e) $\frac{15 +}{18}$

(f) $\frac{18}{3} \times 2 = 12$

(g) $\frac{15 + 12}{18}$

(h) $\frac{15 + 12 -}{18}$

(i) $\frac{18}{9} \times 4 = 8$

(j) $\frac{15 + 12 - 8}{18}$

(k) $\frac{19}{18}$

TUTORIALS 1.5

Evaluate

(1) $\frac{1}{2} + \frac{1}{3} + \frac{1}{8}$

(2) $\frac{3}{4} + \frac{1}{7} + \frac{1}{14}$

(3) $\frac{2}{5} + \frac{3}{10} - \frac{1}{15}$

(4) $\frac{5}{7} - \frac{1}{3} + \frac{2}{21}$

(5) $\frac{3}{100} - \frac{1}{50} + \frac{3}{25}$

(6) $\frac{11}{20} - \frac{5}{40} - \frac{3}{10}$

(7) $\frac{2}{3} - \frac{7}{33} + \frac{5}{11}$

(8) $\frac{1}{6} + \frac{3}{4} - \frac{1}{2} - \frac{1}{8}$

(9) $\frac{11}{20} - \frac{2}{5} - \frac{3}{10} + \frac{14}{15}$

(10) $\frac{2}{3} - \frac{1}{9} - \frac{1}{6} - \frac{1}{2} + \frac{5}{18}$